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to investigate, and I believe, it will be found in the end, that, so far from being accumulated by the sea, the drift of the lowlands of Patagonia has been worn away to its present extent by the continued encroachment of the ocean in the same manner as the northern shores of South America and of Brazil have been.

THE BLIND FISHES OF THE MAMMOTH CAVE AND THEIR ALLIES.*

BY F. W. PUTNAM.

THE blind fish of the Mammoth Cave has from its discovery been regarded with curiosity by all who have heard of its existence, while anatomists and physiologists have considered it as one of those singular animals whose special anatomy must be studied in order to understand correctly facts that have been demonstrated from other sources ; and, in these days of the Darwinian and development theories, the little blind fish is called forth to give its testimony, pro or con.

Before touching upon this point, however, we must call attention to the structure of the fish and its allies, and to others that are either partially or totally blind.

In the lancelet (Branchiostoma) and the hag (Myxine) the eye is described "as simple in form as that of a leach, consisting simply of a skin follicle† coated by a dark pigment, which receives the end of a nerve from the brain." Such an eye speck as this structure gives would only answer for the simple perception of light. In the young‡ of the lampreys (Petromyzon) the eye is very small and placed in a fold of the skin of the head, and probably of little use, as these young remain buried in the sand; but as they attain maturity, and, with it, the parasitic habits of the adult, their eyes are developed to a fair size, thus reversing the general rule in the class.

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*It was intended to put this article in the last number of the NATURALIST in connection with the article on the cave and its insect and crustacean life, but the delay in preparing the plates made it necessary to postpone it. We are therefore obliged to refer the reader to the December number for further information of the fauna of the cave and a short account of the cave itself. — EDS.

† See further on where Prof. Wyman questions this structure.

‡ These young lampreys have been described under the generic name of Ammocœtes, and it was not until 1856, when Prof. Müller discovered the fact of a metamorphosis in the lampreys, that their true position was ascertained. Prof. Müller has traced the history of the common European species and shown that it is three or four years in attaining its perfect form. With this fact before us and with the early stages of the Myxinoids still unknown, have we not some reason for suspecting that the Lancelet may yet prove to be a larval form of the Myxinoids, notwithstanding that it is said to lay eggs ? Why should we not suspect the existence in the very lowest vertebrates of some-

In most other fishes the eyes are developed to a full and even remarkable extent as to size and perfection of sight in water. In Anableps, or the so called four eyed fish of the fresh waters of Central and South America, which belongs to a closely allied family with our blind fish, the *Cyprinodontidæ*, the eyes are not only fully developed, but are divided into an upper and lower portion in such a way, by an opaque horizontal line, as to give the effect of two pupils, by which the fish probably sees as well when following its prey on the surface with its eyes out of water, as when under water. But it is in the interesting family of cat fishes (*Siluridæ*) that we find the most singular arrangement of eyes in perfect adaptation to the diversified modes of life of the numerous species. In this family the eyes assume nearly every possible modification from partial and even total blindness to perfectly developed eyes, and these organs are placed in almost every conceivable position in a fish's head; from the ordinary large eyes on the side, to small ones on top of the head, enabling the fish to see only what is above; to the oval eyes on the side, in some just back of the mouth, situated in such a way that the fish can only see what is in close proximity to its jaws or even below them. Many genera of this family found in South America,* Africa† and Asia,‡ have the eyes so small and buried under the skin or protected by folds or cartilage, as evidently to be of no more use than simply to distinguish light from darkness.

Among the most interesting forms of this family, in this respect, is the genus described by Prof. Cope under the name of *Gronias nigrilabris*. This fish is very closely allied to our common bull

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thing akin to alternate generations, or of larvæ capable of reproduction? Without having any facts to support such an assumption, except that, on general principles, the young of Myxine would probably be very much like Branchiostoma, and that its young is not known, while Branchiostoma has only been found in waters where some species of Myxinoid exists, I think that before the position of the lancelet is firmly established we must know the embryology of the Myxinoids; for should the lancelet prove not to be the young of the Myxinoids, it must necessarily form a distinct class of animals, perhaps as near to the mollusks as to the vertebrates.

* *Pimelodus cyclopium* of Humboldt, *Helogenes*, *Agoniosus* and other genera.

† *Eutropius congensis*.

‡ *Ailia*, *Shilbichthys*, *Bagroides* and other genera.

pout or horned pout, and of about the same size (ten inches in length). It was taken in the Conestoga river in Lancaster Co., Penn., where it is "occasionally caught by fishermen and is supposed to issue from a subterranean stream said to traverse the limestone in that part of Lancaster Co., and discharge into the Conestoga." We quote the following from Prof. Cope's remarks on the fish:* —

> "Two specimens of this fish present an interesting condition of the rudimental eyes. On the left side of both a small perforation exists in the corium, which is closed by the epidermis, representing a rudimental cornea; on the other the corium is complete. Here the eyeball exists as a very small cartilaginous sphere with thick walls, concealed by the muscles and fibrous tissue attached, and filled by a minute nucleus of pigment. On the other the sphere is larger and thinner walled, the thinnest portion adherent to the corneal spot above mentioned; there is a lining of pigment. It is scarcely collapsed in one, in the other so closely as to give a tripodal section. Here we have an interesting transitional condition in one and the same animal, with regard to a peculiarity which has at the same time physiological and systematic significance, and is one of the comparatively few cases where the physiological appropriateness of a generic modification can be demonstrated. It is therefore not subject to the difficulty under which the advocates of natural selection labor, when necessitated to explain a structure as being a step in the advance towards, or in the recession from, any *unknown* modification needful to the existence of the species. In the present case observation on the species in a state of nature may furnish interesting results. In no specimen has a trace of anything representing the lens been found."

When we remember that the lens of the eye in Amblyopsis has been found, even though the eye is less developed in all its parts than in Gronias, it is probable that a careful microscopical examination would show its existence in this genus also.

It is interesting to note that this fish is black above (lighter on the sides and white below), notwithstanding its supposed subterranean habits, and that all the other members of the family having rudimentary or covered eyes are also dark colored, while the blind fishes of the Mammoth Cave and of the caves in Cuba are nearly colorless. This want of color in the latter fishes has been considered as due to their subterranean life. If this be the cause, why should the blind cat fishes retain the colors characteristic of the other members of the family living in open waters?

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*Proceedings of the Academy of Natural Sciences of Philadelphia for 1864, p. 231.

The fishes which in a general way, so far as blindness, tactile sense and mode of life are concerned, come the nearest to the blind fishes of the Mammoth Cave, are those described by Prof. Poey* under the names of *Lucifuga subterraneus* and *L. dentatus.*† These fishes having the broad, flattened, fleshy head, with minute cilia, without external eyes, and inhabiting caves so similar in structure to the Mammoth Cave, make a comparison of them with the fishes of the Mammoth Cave most interesting. This is greatly enhanced by the fact that the Cuban fishes belong to a family of essentially marine habit, quite far removed from Amblyopsis. The fresh water ling (Lota), belonging to the same great group of fishes (though to a distinct family or subfamily) containing the cod on the one hand and the Cuban blind fish on the other, is probably the nearest fresh water relative of the Cuban fish, but the nearest representative yet known is the marine genus Brotula, one species of which is found in the Caribbean Sea.

In the Cuban blind fish we find ciliary appendages on the head and body quite distinctly developed, evidently of the same character as those of Amblyopsis and answering the purpose of tactile organs. These cilia are in the form of small, but plainly visible, protuberances (reminding one of the single fleshy protuberance over the opercular opening just back of the head in Amblyopsis). There are eight of these on top of the head of a specimen I hastily examined, received from Prof. Poey by the Museum of Comparative Zoology, and quite a number arranged in three rows on each side of the body, showing that tactile sense is well developed in this fish; though it is rather singular that the barbels on the jaws, so usually developed as organs of touch in the cod family and its allies, are entirely wanting in this fish.

The brain of *Lucifuga subterraneus*, as represented by the figures of Poey, differs very much from that of *L. dentatus* and of Amblyopsis. In all, the optic lobes are as largely developed as in allied fishes provided with well developed eyes. In *Lucifuga subterraneus* the cerebral lobes are separated by quite a space from the round optic lobes, which are represented as a little larger than the cerebral lobes, and also of greater diameter than the cerebellum; this latter being more developed laterally than in either *L. dentatus* or in Amblyopsis. The three divisions of the brain are represented, from a top view, as nearly complete circles (without division into right and left lobes), of which that representing the optic lobes is slightly the largest. In *L. dentatus* the procencephalon and the optic lobes are represented as divided into right and left lobes, as in Amblyopsis, and the cerebellum does not extend laterally over the medulla oblongata as in *L. subterraneus*, but, as in Amblyopsis (Pl. 1, fig. 1 *d*), is not so broad as the medulla, and, projecting forwards, covers a much larger portion of the optic lobes than is the case in *L. subterraneus*.

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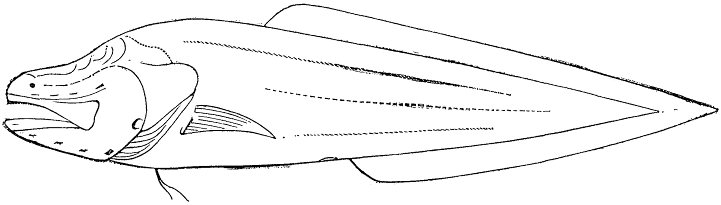
*Memorias Sobre la Historia Natural de la Isla de Cuba, por Felipe Poey. Tomo 2, pp. 95-114. Pls. 9, 10, 11. Habana, 1856-8.

†This species was afterwards referred to the genus *Stygicola* Gill, on account of the presence of palatine teeth which are wanting in the other species. There are also several other good characters, to judge from the figures of the head, skull and brain given by Poey, that would warrant the reference of the fish to a distinct genus from *L. subterraneus.*

The Cuban blind fish has the body, cheeks and opercular bones covered with scales. As in Amblyopsis the eyes exist, but are so imbedded in the flesh of the head as to be of no use. The outline cut here given (Fig. 1), copied from Poey, is very characteristic of the form of the fish, but does not exhibit the fleshy cilia or details of scaling.

Fig. 1.



Blind Fish (*Stygicola dentatus*) from Caves in Cuba.

The first notice that I can find of the Mammoth Cave blind fish is that contained in the "Proceedings of the Academy of Natural Sciences of Philadelphia," Vol. 1, page 175, where is recorded the presentation of a specimen to the Academy by W. T. Craige, M. D., at the Meeting held on May 24, 1842, in the following words :—

> "A white, eyeless crayfish (*Astacus Bartoni?*) and a small white fish, also eyeless (presumed to belong to a subgenus of Silurus), both taken from a small stream called the 'River Styx' in the Mammoth Cave, Kentucky, about two and one-half miles from the entrance."

Dr. DeKay in his "Natural History of New York, Fishes," page 187, published in 1842, describes the fish, from a poor specimen in the Cabinet of the Lyceum of Natural History of New York, under the name of *Amblyopsis** *spelœus*.† DeKay's description is on the whole so characteristic of the fish as to leave no doubt as to the species he had before him, though the statement that it has eight rays supporting the branchiostegal membrane (instead of six), and that the eyes are "large" but under the skin, must have been due to the bad condition of his specimen and to his taking the fatty layer covering the minute eyes for the eyes themselves, as pointed out by Prof. Wyman. Dr. DeKay places the genus with the Siluridæ (cat fishes) but at the same time questions its connection with the family and says that it will probably form the type of a new family. In 1843 Prof. Jeffries Wyman‡ gave an account of the dissection of a specimen in which he could not find a trace of the eye or of the optic nerve, probably owing to the condition of the specimen, as he afterwards§ found the eye spots, and made out the structure of the eye. When describing the brain, Prof. Wyman calls attention to the fact of the optic lobes being as well developed as in allied fishes with well developed eyes, and asks if this fact does not indicate that the optic lobes are the seat of other functions as well as that of sight. He also calls attention to the papillæ on the head as tactile organs furnished with nerves from the fifth pair.

Dr. Theo. Tellkampf‖ was the first to point out the existence of the rudimentary eyes from dissections made by himself and Prof. J. Müller, and to state that they can be detected in some specimens as black spots under the skin by means of a powerful lens. Prof. Wyman afterwards detected the eye through the skin in several specimens. Dr. Tellkampf also was the first to call attention to the "folds on the head, as undoubtedly serving as organs of touch, as numerous fine nerves lead from the trigeminal nerve to them and to the skin of the head generally."

It is also to Dr. Tellkampf that we are indebted for the first figure of the fish,¶ and for figures illustrating the brain, and internal organs. The descriptions of the anatomy of the fish by Drs.

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* Obtuse vision. † Of a cave.

‡ Silliman's Journal, Vol. 45, p. 94.

§ Proceedings Boston Soc. Nat. Hist., Vol. 4, p. 395. 1853.

‖ Müller's Archiv. fur Anat., 1844. p. 392. Reprinted in the New York Journal of Medicine for July, 1845. p. 84, with plate.

¶ The only other figures of the species, that I am aware of, are the simple outlines given in Poey's Mem. de Cuba, the woodcut in Wood's Illustrated Natural History and the cut in Tenney's Zoology. None of these figures are very satisfactory.

Tellkampf and Wyman are all that have ever been written on the subject of any importance, with the exception of the description of the eye by Dr. Dalton, whose paper, in the "New York Medical Times," Vol. 2, p. 354, I have not seen. Prof. Poey gives a comparison of portions of the structure with that of the Cuban blind fishes.

Dr. Tellkampf proposed the name of *Heteropygii** for the family of which, at the time, a single species from the Mammoth Cave was the only known representative, and makes a comparison of the characters with those of *Aphredoderus Sayanus*, a fish found only in the fresh waters of the United States, and belonging to the old family of Percoids, but now considered as representing a family by itself, though closely allied to the North American breams (Pomotis), and having the anal opening under the throat as in the blind fish.

Dr. Storer,† not knowing of Dr. Tellkampf's paper, proposed the name of *Hypsæidæ*, for the blind fish, and placed it between the minnow and the pickerel families, in the order of Malacopterygian, or soft rayed, fishes. According to the system adopted by Dr. Günther, it stands as closely allied to the minnows, *Cyprinodontidæ* (many of which are viviparous and have the single ovary and general character of the blind fish), and the shiners, *Cyprinidæ*, of the order of Physostomi. Dr. Tellkampf, in discussing the relations of the family, points out its many resemblances to the family of Clupesoces, and its differences from the Siluroids, Cyprinodontes and Clupeoids, with which it has more or less affinity, real or supposed. Prof. Cope in his paper on the Classification of Fishes‡ places the Amblyopsis in the order of Haplomi with the shore minnows, pickerel and mud fish, and in an article on the Wyandotte Cave,§ he says that the Cyprinodontes (shore minnows) are its nearest allies. This arrangement by Prof. Cope places the Haplomi between the order containing the herrings and that containing the electric eel of South America, all included with the garpike, dog fish of the fresh waters (Amia), cat fishes, suckers and eels proper, etc., etc., in the division of Physostomi as limited by him.

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*From the advanced position of the terminus of the intestine being so different from the position which it has in ordinary fishes.

† Synopsis of the Fishes of North America, published in 1846.

‡ American Naturalist, Vol. 5, p. 579, 1871.

§ Indianapolis Daily Journal of September 5, 1871. Reprinted in Ann. Mag. Nat. Hist., Nov., 1871.

Prof. Agassiz in 1851* stated that the blind fish was an aberrant form of the Cyprinodontes.

Thus all those authors who have expressed an opinion as to the position which the fish should hold in the natural system have come to the same conclusions as to the great group, division, or order, into which it should be placed. For all the terms used above, when reduced to any one system, bring Amblyopsis into the same general position in the system; its nearest allies being the minnows, pickerels, shiners and herrings; and unless a careful study of its skeleton should prove to the contrary, we must, from present data, consider the family containing Amblyopsis as more nearly allied to the Cyprinodontes, or our common minnows having teeth on the jaws, than to any other family, differing from them principally by the structure of the several parts of the alimentary canal and the forward position of its termination.

I have thus far mentioned only one species of blind fish from the cave, the *Amblyopsis spelœus.* The waters of the cave not only contain another species of blind fish, differing from Amblyopsis in several particulars, especially by its smaller size and by being without ventral fins, which I have identified as the *Typhlichthys subterraneus* of Dr. Girard; but also a fish with well developed eyes, as proved by the account given by Dr. Tellkampf and by the drawing of a fish found by Prof. Wyman, in 1856, in the stomach of an Amblyopsis he was dissecting. In order to call attention to the fact that fishes with eyes are at times, if not always, in the waters of the cave, I have reproduced the drawing by Prof. Wyman on plate 1, fig. 13. It is very much to be regretted that the specimen is not now to be found, and that it was so much acted on by the gastric juice as to destroy all external characters by which it could be identified from the drawing, which is of about natural size. Dr. Tellkampf's remarks on the fish with eyes are as follows: —

> "Besides the colorless blind-fish, there are also others found in the cave, which are black, commonly known by the name of 'mud-fish.' I saw a dark-colored fish in the water, but did not succeed in catching it. The latter are said to have eyes, and are entirely dissimilar to the blind-fish."

The name "mud-fish," given to this fish with eyes, and the statement that it is of a dark color, together with the drawing by Prof.

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*Silliman's Journal. p. 128.

Wyman of the fish found in the stomach of the blind fish, showing the position of the dorsal fin to be the same as in the fish commonly called mud fish in the fresh waters of the Middle, Western and Southern States, perhaps, indicates the fish with eyes to be a species of *Melanura.** This fish is called mud fish from the habit it has of burying itself in the mud, tail first,† to the depth of two to four inches, and of remaining buried in the mud in our western ditches during a time of drought. This habit, perhaps, in a measure fits it for a subterranean life. The occurrence of a fish belonging to the same family with the blind fish, but with well developed eyes, in the subterranean streams in Alabama, as mentioned further on and figured on Pl. 2, fig. 4, however, renders it probable that the cave fish with eyes may be the same or an allied species, and the drawing by Prof. Wyman would answer equally as well for it.

The fact that the Amblyopsis succeeded in catching a fish of, probably, very rapid and darting movements, shows that the tactile sense is well developed and that the blind fish must be very active in the pursuit of its prey; probably guided by the movement which the latter makes in the water so sensibly influencing the delicate tactile organs of the blind fish that it is enabled to follow rapidly, while the pursued, not having the sense of touch so fully developed, is constantly encountering obstacles in the darkness.

In describing the habits of the blind fish Dr. Tellkampf says:—

> "It is found solitary, and is very difficult to be caught, since it requires the greatest caution to bring the net beneath them without driving them away. At the slightest motion of the water they dart off a short distance and usually stop. Then is the time to follow them rapidly with a net and lift them out of water. They are mostly found near stones or rocks which lie upon the bottom, but seldom near the surface of the water."

Prof. Cope, in describing the habits of the blind fish which he

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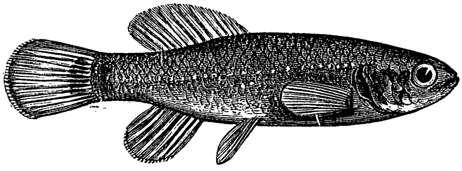
* Dr. Günther considers the genus Melanura of this country to be synonymous with Umbla of Europe. In each country only one species has been as yet satisfactorily described.

† See the interesting notes on the habits of the mud minnow, by Dr. Abbott in American Naturalist, Vol. 4, pages 107 and 388, with figure of the fish on page 385, which we here reproduce for comparison.

Fig. 2.



Mud fish (*Melanura limi*).

obtained in a stream that passes into the Wyandotte Cave, though he entered it by means of a well in the vicinity of the cave, says that: —

> "If these Amblyopses be not alarmed they come to the surface to feed, and swim in full sight like white aquatic ghosts. They are then easily taken by the hand or net, if perfect silence be preserved, for they are unconscious of the presence of an enemy except through the sense of hearing. This sense is, however, evidently very acute, for at any noise they turn suddenly downward, and hide beneath stones, etc., on the bottom. They must take much of their food near the surface, as the life of the depths is apparently very sparse. This habit is rendered easy by the structure of the fish, for the mouth is directed upwards, and the head is very flat above, thus allowing the mouth to be at the surface."

The blind fish has a single ovary, in common with several genera of viviparous Cyprinodontes. In three female specimens of Amblyopsis which I have opened, the ovary was distended with large eggs, but no signs of the embryo could be traced. In these three specimens it was the right ovary that was developed, and this, as in the figure (Plate 2, fig. 1*c*), was by the side of the stomach and did not extend beyond it. The number of eggs contained in the ovary was not far from one hundred in the specimen figured. As the embryos develop, the mass probably pushes further back in the cavity and also extends the abdominal walls. That the fish is viviparous is proved by the statement made by Mr. Thompson before the Belfast Natural History Society,* that one of the blind fishes from the cave, four and a half inches long, "was put in water as soon as captured, where it gave birth to nearly twenty young, which swam about for some time, but soon died. These, with the exception of one or two, were carefully preserved, and fifteen of them are now before us [at the meeting, I wish they were here], they were each four lines in length."

It is singular that no mention is made regarding these young, as to the presence or absence of eyes, and, as if it was fated that this important point should remain unnoticed as long as possible, it is equally singular that Dr. Steindachner omitted to examine some very young specimens which he received from a friend a few months since and sent to the Vienna Museum, where they will remain unexamined until he returns there. I saw the Doctor only a week after these, to me, interesting specimens had been sent abroad, and he was as grieved as I was disappointed at my being just too late to take advantage of them.

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*Annals and Mag. of Natural History, Vol. xiii, pp. 112, 1844.

At what time the young are born has never been stated, but judging from such data as I can at present command, I think that it must be during the months of September and October. Specimens collected during those months would probably contain embryos in various stages of development, the examination of which would undoubtedly lead to most interesting results.

Prof. Wyman has most generously placed in my hands his unpublished notes and drawings of the several dissections he has made of Amblyopsis, as well as his specimens and dissections. Many of these drawings are reproduced on Plate 1, and will, with his notes which I here give, greatly enhance the value of this article, as his dissections have been made with the utmost care, and with a patience and delicacy that only a master hand attains. It will therefore be understood that, in giving credit to Prof. Wyman in the following pages, I refer to his unpublished notes, except when the quotation is given from a special work. In quoting his description of the eye and ear from "Silliman's Journal" I have changed the references so as to refer to his drawings reproduced on Plate 1, and not to the three cuts given in "Silliman's Journal," though the figures of the brain and of the otolite were copied from those cuts.

The largest specimens I have seen of Amblyopsis are several males and females, each from four to four and a half inches in length, which seems to be about as large as the fish grows, though Dr. Günther mentions a specimen in the British Museum of five inches in length. The largest specimen captured of late years is said to have been taken, during the summer of 1871, and sold for ten dollars to a person who was so desirous of securing the precious morsel that he had it cooked for his supper. The smallest specimen I have seen was one and nine-tenths inches in length. The general shape and character of the fish is best shown by the figures on plates 1 and 2.

"The whole head, above and below, is destitute of scales, the naked skin extending backwards on the sides to the base of the pectoral fins; the scaly portion of the body above ends in a semicircular edge covering the space between the upper ends of the opercula. The skin covering the middle region of the head is smooth, but on either side is provided with numerous transverse and longitudinal ridges (Pl. 1, fig. 7), which are, on the whole, regularly arranged. The first row of transverse ridges, eight or nine in number, begins between the nostrils and extends backwards, diverging from the median line. The third ridge is crossed at its outer end by a longitudinal one, as are also two others farther back. The second and third rows, situated, in part, on the sides and, in part, on the under surface, are less regular than the preceding. A fourth, on the borders of the operculum, is still less well defined. The transverse are also crossed here by longitudinal ridges. About ten vertical ridges, also provided with papillæ, and similar to those on the head, are visible on the sides extending from the pectoral fins to the tail, but are not so well defined as those on the head. The skin of the head is of extreme delicacy and is covered by a very thin, loose layer of epithelium."—WYMAN.

"The larger ridges have between twenty and thirty papillæ, many of these having a cup-shaped indentation at the top, in which a delicate filament is, in some instances, seen (Pl. 1, fig. 9). These papillæ are largely provided with nervous filaments, and, as is obvious from their connection with branches of the fifth pair of nerves, must be considered purely tactile, and the large number of them shows that tactile sensibility is probably very acute and in some measure compensates for the virtual absence of the sense of sight. Plate 1, fig. 8, represents one of the ridges of the head magnified, showing the papillæ of which it is made up, and figure 9 shows three papillæ still more enlarged. Two of these show a cup-shaped cavity at the top, and the short, slender filament already mentioned. The surface of the papillæ is covered with loosely connected epithelium cells. Fig. 10 shows the nervous filaments distributed to the papillæ: *a*, a branch of the fifth pair of nerves passing beneath the papillary ridge and sending filaments to each papilla. These papillary branches interchange filaments, forming a nervous plexus in connection with each ridge. This figure of the nerves was drawn with a camera lucida, from a specimen treated with acetic acid."—WYMAN.

"Plate 1, fig. 6, represents a double system of subcutaneous canals, which extend the whole length of the head, but were not traced farther back than the edge of the naked or scaleless skin which covers it. Forwards they bifurcate, nearly encircling the nasal cavity, towards the middle line ending in a blind pouch.

The lateral branch was not traced distinctly to an end, but seemed to connect with the olfactory cavity. The walls of these canals are exceedingly delicate and easily overlooked."—WYMAN.

"Plate 1, fig. 5, shows the globe of the eye with the optic nerve (*c*), as seen under the microscope. The lens (*b*) is detached from its proper place by the pressure of the glass. Irregularly arranged muscular bands are attached to the exterior of the globe (*a*, *a*, *a*, *a*), but were not recognized as the homologues of the muscles of the normal eye of fishes; nevertheless, they indicate that the globe was moveable."—WYMAN.

"In the three specimens recently dissected, the eyes were exposed only after the removal of the skin, and the careful separation from them of the loose areolar tissue which fills the orbit. In a fish four inches in length the eyes measured one-sixteenth of an inch in their long diameter, and were of an oval form and black. A filament of nerve (Pl. 1, fig. 3*a*) was distinctly traced from the globe to the cranial walls, but the condition of the contents of the cranium, from the effects of the alcohol, was such as to render it impracticable to ascertain the mode of connection of the optic nerve with the optic lobes.

Examined under the microscope with a power of about twenty diameters, the following parts were satisfactorily made out (Pl. 1, fig. 3): 1st, externally an exceedingly thin membrane, *b*, which invested the whole surface of the eye and appeared to be continuous with a thin membrane covering the optic nerve, and was therefore regarded as a sclerotic; 2d, a layer of pigment cells, *d*, for the most part of a hexagonal form, and which were most abundant about the anterior part of the eye; 3d, beneath the pigment a single layer of colorless cells, *c*, larger than a pigment cell, and each cell having a distinct nucleus; 4th, just in front of the globe, a lenticular-shaped, transparent body, *e* [see also fig. 4], which consisted of an external membrane containing numerous cells with nuclei. This lens-shaped body seemed to be retained in its place by a prolongation forwards of the external membrane of the globe; 5th, the globe was invested by loose areolar tissue, which adhered to it very generally, and in some instances contained yellow fatty matter; in one specimen it formed a round spot, visible through the skin on each side of the head, which had all the appearance of a small eye; its true nature was determined by the microscope only. It is not improbable that the appearance just referred to may have misled Dr. DeKay—where he states that the eye exists of the usual size, but covered by the skin.

If the superficial membrane above noticed is denominated correctly the *sclerotic*, then the pigment layer may be regarded as the representation of the *choroid*. The form as well as the position of the transparent nucleated cells within the choroid correspond for the most part with the *retina*. All of the parts just enumerated are such as are ordinarily developed from and in connection with the encephalon, and are not in any way dependent upon the skin. But if the lenticular-shaped body is the true representative of the crystalline lens, it becomes difficult to account for its presence in Amblyopsis according to the generally recognized mode of its development (since it is usually formed from an involution of the skin) unless we suppose that after the folding in of the skin had taken place in the embryonic condition, the lens retreated from the surface, and all connection with the integument ceased.[*]

According to Quatrefages, however, the eye of Amphioxus [†] is contained wholly in the cavity of the dura mater, and yet it has all the appearance of being provided with a lens. If his description be correct, then the mode of development as well as the morphology of the eye in this remarkable fish is different from that of most other vertebrates, since the lens never could have been formed from an involution of the skin, nor could the eye with its lens, as Prof. Owen asserts, be a modified cutaneous follicle. Whatever views be taken with regard to the development of the eye of the blind fish, the anatomical characters which have been enumerated show, that though quite imperfect as we see it in the adult, it is constructed after the type of the eyes of other vertebrates. It certainly is not adapted to the formation of images, since the common integument and the areolar tissue which are interposed between it and the surface, would prevent the transmission of light to it except in a diffused condition. No pupil or anything analogous to an iris was detected, unless we regard as representing the latter the increased number of pigment cells at the anterior part of the globe.

It is said that the blind fishes are acutely sensitive to sounds as well as to undulations produced by other causes in the water. In the only instance in which I have dissected the organ of hearing (which I believe has not before been noticed), all its parts were largely developed, as will be seen by reference to Pl. 1, fig. 1 *e*. As regards the general structure, the parts do not differ materially from those of other fishes except in their proportional dimensions. The semi-circular canals are of great length, and the two which unite to enter the vestibule by a common duct, it will be seen, project upwards and inwards under the vault of the cranium, so as to approach quite near to the corresponding parts of the opposite side. The otolite contained in the utricle was not remarkable, but that of the vestibule (Pl. 1, fig. 2) and seen in dotted outline in fig. 1 *e* is quite large when compared with that of a Leuciscus of about the same dimensions as the blind-fish here described."—WYMAN, *Silliman's Journal, Vol.* 17, *p.* 259, 1854.

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[*] In birds and mammals there is a stage of development where the lids come together and firmly unite, to separate again when the animal "gets his eyes open." In the mole rat (*Spalax typhlus*) of Siberia, the lids never open, and the eyes remain through life covered with hairy skin. It is not improbable that in Amblyopsis something analogous to this, a closing of the skin over the eye, may have taken place.—J. W.

[†] I have used the prior name of *Branchiostoma* in this paper when speaking of the Lancelet.

The *Amblyopsis spelœus* undoubtedly has quite an extensive distribution, probably existing in all the subterranean rivers that flow through the great limestone region underlying the Carboniferous rocks in the central portion of the United States. Prof. Cope obtained specimens from the Wyandotte Cave and from wells in its vicinity, and in the Museum of Comparative Zoology at Cambridge there is a specimen labelled "from a well near Lost River, Orange Co., Ind.," which, with those from the Wyandotte Cave, is conclusive evidence of its being found on the northern side of the Ohio* as well as on the southern, in the rivers of the Mammoth Cave. I have been able to examine a number of specimens from the Mammoth Cave, and have carefully compared with them the one from the well in Orange Co., Ind., and find that the specific characters are remarkably constant.

In 1859† Dr. Girard described a blind fish, received by the Smithsonian Institution from J. E. Younglove, Esq., who obtained it "from a well near Bowling Green, Ky." The general appearance of this fish, which was only one and a half inches in length, was that of *Amblyopsis spelœus*, but it differed from that species in several characters, especially by the *absence* of ventral fins. Dr. Girard therefore referred the fish to a distinct genus under the name of *Typhlichthys*‡ *subterraneus*. Dr. Günther§ considers this fish a variety of *Amblyopsis spelœus* and records the specimen in the British Museum "from the Mammoth Cave," as "half-grown." ||

By the kindness of Prof. Agassiz, I have been enabled to examine nine specimens of *blind fish without ventrals*, in the Museum of Comparative Zoology. Seven of these were collected in the Mammoth Cave by Mr. Alpheus Hyatt in September, 1859. One was from Moulton, Lawrence County, Alabama, presented by Mr. Thomas Peters; and another from Lebanon, Wilson Co., Tennessee; presented by Mr. J. M. Safford. It is not stated whether

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*I have also been informed by Mr. Holmes of Lansing, Mich., that *blind fishes* have been drawn out of wells in Michigan.

†Proceedings Acad. Nat. Sci. Philad., p. 63.

‡Blind fish.

§Catalogue of Fishes in the British Museum, Vol. 7, p. 2, 1868.

||The largest specimen I have seen of Typhlichthys is one and seventeen-twentieths inches in length, and the smallest Amblyopsis one and eighteen-twentieths inches.

these latter came from wells or caves, but probably from wells. They are all of about the same size, one and one-half to two inches in length, and are constant in their characters. Moreover, four of the seven specimens from the Mammoth Cave were females with eggs. These eggs were as large in proportion as those from Amblyopsis. The ovary was single and situated on the right side of the stomach, as in Amblyopsis. The difference in the number of eggs was very remarkable, each of the four specimens examined having but about thirty eggs in the ovary, while in three females of Amblyopsis (all, however, of nearly three times the size of Typhlichthys) there were about one hundred eggs in each. As in both species there were no signs of the embryos in the eggs, it is not probable that any of the eggs had been developed and the young excluded, nor is it at all likely that the great variation in the number of eggs would simply indicate different ages. By a reference to the figures (Pl. 2), it will be seen that the pyloric appendages, stomach and scales of the two fishes are different. For these reasons, taken in connection with the absence of ventral fins, I have no hesitation in accepting Dr. Girard's name as valid for this genus, of which we thus far know of but one species, with a subterranean range from the waters of the Mammoth Cave, south to the northern portion of Alabama. In this connection it would be most interesting to know the relations of the "blind fishes" said to have been found in Michigan. For thus far we have Typhlichthys limited to the central and southern portion of the subterranean region, Amblyopsis to the central, and the species in the northern portion undetermined.

In 1853, on his return from a tour through the southern and western states, Prof. Agassiz gave a summary of some of his ichthyological discoveries in a letter to Prof. J. D. Dana.* In this letter are the following remarks: —

> "I would mention foremost a new genus which I shall call *Chologaster*, very similar in general appearance to the blind fish of the Mammoth Cave, though provided with eyes; it has, like Amblyopsis, the anal aperture far advanced under the throat, but is entirely deprived of ventral fins; a very strange and unexpected combination of characters. I know but one species, *Ch. cornutus* Ag. It is a small fish scarcely three inches long, living in the ditches of the rice fields in South Carolina. I derive its specific

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* Published in American Journal of Sci. and Arts, Vol. 16 (2d series), p. 134, 1853.

name from the singular form of the snout, which has two horn-like projections above."

This is the only information ever published regarding this interesting fish and the only specimens known are those on which Prof. Agassiz based the above remarks.

By the kindness of Professor L. Agassiz, who has placed all the specimens of the family contained in the Museum of Comparative Zoology in my hands for study, I am enabled to give a figure and description of this interesting species from the three specimens in the Museum, which were labelled as the originals of *Chologaster cornutus* Ag., from Waccamaw, S. C., presented by Mr. P. C. J. Weston, 1853. The largest of these specimens was distended with eggs and I was enabled to compare the ovary with that of Amblyopsis. From its being single and the eggs very large, I have no doubt that it is a viviparous fish like the other genera of the family. The position of the ovary behind the stomach, as shown in fig. 2*c*, plate 2, and the presence of four pyloric appendages (Pl. 2, fig. 2*a*) instead of two, as in Amblyopsis (fig. 1*a*) and Typhlichthys (fig. 3*a*), are good internal characters, separating it from the other genera, independently of the presence of eyes and the absence of ventral fins and papillary ridges.

The stability of the internal characters I have mentioned was most unexpectedly substantiated by the discovery of a second species (Pl. 2, figs. 4, 4*a*) of the genus among the specimens in the Museum of Comparative Zoology. I have the pleasure of dedicating this species* to Professor Agassiz, not only in kindly remembrance of the eight years I was associated with him as student and assistant, but also because the fish so well illustrates the decided position he has taken relative to the immutability of species.

The only specimen known of this second species was drawn from a well in Lebanon, Tenn., and presented to the Museum by Mr. J. M. Safford, Jan., 1854. It is a more slender fish than *C. cornutus*, but the intestine follows the same course and the four pyloric appendages are present as in that species.

In the genus Chologaster† we have all the family characters as well expressed as in the blind species, though it differs from Amblyopsis and Typhlichthys by the presence of eyes, the absence of papillary ridges on the head and body, and by the longer intestine and double the number of pyloric appendages, as well as by the position of the ovary; and agrees with Typhlichthys by the absence of ventral fins. Amblyopsis and Typhlichthys are nearly colorless, while *Chologaster Agassizii* is of a brownish color similar to many of the minnows, and *C. cornutus* is brownish yellow, with dark, longitudinal bands.

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* A Synopsis of this family with descriptions of the four species will appear in the "Report of the Peabody Academy of Science for 1871."

† Literally "bile-stomach;" probably named from the yellow color of the fish.

Among the most interesting points in the history of this genus is the fact of its occurring in two widely different localities, *C. Agassizii* having been found in a well, in the same vicinity (probably in the same well) with a specimen of Typhlichthys, and undoubtedly belonging to the same subterranean fauna west of the Appalachian ridge, while *C. cornutus* belongs to the southern coast fauna of the eastern side of that mountain chain, and is thus far the only species of the family known beyond the limits of the great subterranean region of the United States.

Having now given an outline of the structure, habits and distribution of the four species belonging to the family, and recapitulated the known facts, we are better able to consider the bearings of the peculiar adaptation of the blind fishes, in the Mammoth and other caves, to the circumstances under which they exist.

Prof. Cope in stating, in his account of the blind fish of the Wyandotte Cave, "that the projecting under jaw and upward direction of the mouth renders it easy for the fish to feed at the surface of the water, where it must obtain much of its food," suggests that: —

> "This structure also probably explains the fact of its being the sole representative of the fishes in subterranean waters. No doubt many other forms were carried into the caverns since the waters first found their way there, but most of them were like those of our present rivers, deep water or bottom feeders. Such fishes would starve in a cave river, where much of the food is carried to them on the surface of the stream. . . . . . The shore minnows are their nearest allies, and many of them have the upturned mouth and flat head. . . . . . Fishes of this, or a similar family, enclosed in subterranean waters ages ago, would be more likely to live than those of the other, and the darkness would be very apt to be the cause of the atrophy of the organs of sight seen in the Amblyopsis."

This suggestion was undoubtedly hastily made by Prof. Cope when writing the letter which was printed in the "Indianapolis

Journal," and were it not that the article has been reprinted in the "Annals and Magazine of Natural History," I should not criticise the statement made in an off-hand letter for publication in a newspaper; for with Prof. Cope's knowledge of fishes it could simply be a hasty thought which he put on paper, when he suggests that it is because the Cyprinodontes have a mouth directed upwards and are surface feeders that they were better adapted to a subterranean life than other fishes, and hence maintained an existence, while other species, which he supposes were introduced into the subterranean streams at the same time, died out.

If the fishes of the subterranean streams came from adjoining rivers, why were not many of the Percoids, Cyprinoids and other forms, that are as essentially surface feeders as the Cyprinodontes (many of the latter are purely "mud feeders"), as capable of maintaining an existence in the subterranean waters as any species of the latter? Neither is it necessary for us to assume that the structure of the fish should be adapted to feeding on the surface, for not only have we in the blind cat fish, described by Prof. Cope himself, from the subterranean stream in Pennsylvania, an example of a fish belonging to an entirely different family of bottom feeders, thriving under subterranean conditions, but the blind fishes of the Cuban caves are of the great group of cod fishes which are, with hardly an exception, bottom feeders. The fact that the food of the blind fishes of the Mammoth Cave consists in great part of the cray fish found in the waters of the cave, as shown by the contents of several stomachs I have examined, and also that one blind fish at least made a good meal of another fish, as already mentioned, shows that they are not content with simply waiting for what is brought to them on the surface of the water, and that they are probably as much bottom as surface feeders.

Again, in regard to the sense of sight, why is it necessary to assume that because fishes are living in streams where there is little or no light, that it is the cause of the non development of the eye and the development of other parts and organs? If this be the cause, how is it that the Chologaster from the well in Tennessee, or the "mud fish" of the Mammoth Cave are found with eyes? Why should not the same cause make them blind if it made the Amblyopsis and Typhlichthys blind? Is not the fact, pointed out by Prof. Wyman, that the optic lobes are as well developed in Amblyopsis as in allied fishes with perfect eyes, and, I may add, as well developed as those of *Chologaster cornutus*, an argument in favor of the theory that the fishes were always blind and that they have not become so from the circumstances under which they exist? If the latter were the case and the fishes have become blind from the want of use of the eyes, why are not the optic lobes also atrophied, as is known to be the case when other animals lose their sight? I know that many will answer at once that Amblyopsis and Typhlichthys have gone on further in the development and retardation of the characters best adapting them to their subterranean life, and that Chologaster is a very interesting transitionary form between the open water Cyprinodontes and the subterranean blind fishes. But is not this assumption answered by the fact that Chologaster has every character necessary to place it in the same family with Amblyopsis and Typhlichthys, while it is as distinctly and widely removed from the Cyprinodontes as are the two blind genera mentioned?

Assuming, for the moment, that Chologaster is a transitional form between the surface feeding Cyprinodontes, and Typhlichthys and Amblyopsis, let us recapitulate the characters that distinguish the different forms and see if they exhibit transitions, and if Chologaster is traversing the slow developmental road to Amblyopsis.

Allowing all characters embraced in the general structure of the skeleton, brain, scales, fins, etc., as ordinal, and common to both Cyprinodontes and Heteropygii, we will recapitulate only such as can be considered of family and generic value in the two groups.

	CYPRINODONTES.	CHOLOGASTER.	TYPHLICHTHYS.	AMBLYOPSIS.
Surface feeders.	In part.	Unknown.	Partially.	The same.
Intestine.	In many genera long and convoluted, in others short and with single turn.	Moderately long with two turns.	Shorter with two turns.	The same.
Stomach & pyloric appendages.	In most, if not all, stomach not well defined from intestine and without appendages.	Stomach well defined, cœcal, with two pyloric appendages on each side.	The same, with one pyloric appendage on each side.	The same.
Viviparous.	Many genera.	Probably.	Probably.	Undoubtedly.
Ovary.	Single in viviparous genera* and placed by the side of intestine in some and posterior in others.	Single and placed behind the stomach.	Single and placed at side of stomach.	The same.

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* The ovary is also single in other genera of viviparous fishes belonging to distinct orders.

Anal opening.	In normal position.	Forward of pectorals.†	The same.	The same.
Air bladder.	Present in few genera.‡	Present.	The same.	The same.
Scales.	On body regularly imbricated and loosely attached.	Irregularly arranged, firmly attached by being covered in great part by the cuticle.	The same.	The same.
Head with scales or naked.§	With scales.	Naked.	The same.	The same.
Tactile papillæ‖ *on the head and body.*	Absent.	Absent.	Very prominent as ridges on the head and sides of body.	The same.
Ventral fins.¶	Present in most genera, absent in at least two.	Absent.	Absent.	Present.
*Eyes.***	Well developed in all.	Well developed and normal.	Rudimentary†† and of no use.	The same.
Habitat.	Fresh water; brackish water; salt water.	Limestone water of subterranean rivers. Brackish water?	Limestone water of subterranean rivers.	The same.
Geographical range.	Nearly all parts of the world.	One species in subterranean streams of S. central portion of the U. S; a 2d species in the So. Atl. coast fauna of U. S.	Central & southern portion of subterranean fauna of United States.	Central and N. central portion of same.

From this brief comparison of some of the prominent characters of the genera of the Heteropygii with the Cyprinodontes, their acknowledged nearest allies, we can only trace what could be regarded as a transition, or an acceleration, or a retardation of development, in simply those very characters, of eyes and ventral fins, that are in themselves of the smallest importance in the structure (permanence of character considered) of a fish, and, as if to show that they were of no importance in this connection, we find in the same cave, blind fishes with ventrals and without, and in the same subterranean stream, a blind fish and another species of the family with well developed eyes.

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† Aphredoderus and Gymnotus, and other genera of distinct orders have this forward position of the anus also.

‡ The air bladder is in several families present in some species and absent in others.

§ The presence or absence of scales on the head, or on portions of it, is a generic character subject to great variation in many families and quite constant in others.

‖ I cannot recall anything but the barbels on the head and jaws of many genera, of Cyprinoids, Siluroids, Gadoids, etc., etc., that can be said to be tactile organs, among fishes, with the exception of the fleshy papillæ on the head and body of the blind fishes of the American and Cuban caves, and the filaments of the fin rays of many fishes and the fleshy ventral rays of the Gurnards.

¶ Of all fins, the ventrals are the most likely to deviate from their normal structure and position. Their presence or absence, as exhibited in many families, and often by different ages of the same fish, and the great variation in their position in different genera of the same family, render any change in them of either generic, specific, or individual character, or simply indicative of age (as they are lost in some adult fishes while present in the young, and in others not developed until after the other fins).

** As I have alluded to the fact, in the first part of this paper, the eyes of fishes are no more the constant and unvarying part of the fish structure than the ventral fins, and like them are subject to almost every conceivable variation in position in the head, and perfection in structure.

†† The largest specimen I have seen of Typhlichthys, is less than two inches in length, and as the eye of an Amblyopsis of twice the size is not over a 32d of an inch in width, it must be very small indeed in Typhlichthys, and I confess to not being able to find it in an ordinary dissection, assisted only by a good lens.

If it is by acceleration and retardation of characters that the Heteropygii have been developed from the Cyprinodontes, we have indeed a most startling and sudden change of the nervous system. In all fishes the fifth pair of nerves send branches to the various parts of the head, but in the blind fishes these branches are developed in a most wonderful manner, while their subdivisions take new courses and are brought *through* the skin, and their free ends become protected by fleshy papillæ, so as to answer, by their delicate sense of touch, for the absence of sight. At the same time the principle of retardation must have been at work and checked the development of the optic nerve and the eye (which probably exists externally in the young fish), while acceleration has caused other portions of the head to grow and cover over the retarded eye.

Now, if this was the mode by which blindness was brought about and tactile sense substituted, why is it that we still have *Chologaster Agassizii* in the same waters, living under the same conditions, but with no signs of any such change in its senses of sight and touch? It may be said that the Chologaster did not change because it probably had a chance to swim in open waters and therefore the eyes were of use and did not become atrophied. We can only answer, that if the Chologaster had a chance for open water, so did the Typhlichthys and yet that is blind.

If the Heteropygii have been developed from Cyprinodontes, how can we account for the whole intestinal canal becoming so singularly modified, and what is there in the difference of food or of life that would bring about the change in the intestine, stomach and pyloric appendages, existing between Chologaster and Typhlichthys in the same waters? To assume, that under the same conditions, one fish will change in all these parts and another remain intact, by the blind action of uncontrolled natural laws, is, to me, an assumption at variation with facts as I understand them.

Looking at the case from the standpoint which the facts force me to take, it seems to me far more in accordance with the laws of nature, as I interpret them, to go back to the time when the region now occupied by the subterranean streams, was a salt and brackish water estuary, inhabited by marine forms, including the brackish water forms of the Cyprinodontes and their allies (but not descendants) the Heteropygii. The families and genera having the characters they now exhibit, but most likely more numerously represented than now, as many probably became exterminated as the salt waters of the basin gradually became brackish and more limited, as the bottom of this basin was gradually elevated, and finally, as the waters became confined to still narrower limits and changed from salt to brackish and from brackish to fresh, only such species would continue as could survive the change, and they were of the minnow type represented by the Heteropygii, and perhaps some other genera of brackish water forms that we have not yet discovered.

In support of this hypothesis we have one species of the family, *Chologaster cornutus*, now living in the ditches of the rice fields of South Carolina, under very similar conditions to those under which others of the family may have lived in long preceding geological times; and to prove that the development of the family was not brought about by the subterranean conditions under which some of the species now live, we have the one with eyes living with the one without, and the South Carolina species to show that a subterranean life is not essential to the development of the singular characters which the family possess.

That a salt or brackish water fish would be most likely to be the kind that would continue to exist in the subterranean streams, is probable from the fact that in all limestone formations caves are quite common, and would in most instances be occupied first with salt water and then brackish, and finally with fresh water so thoroughly impregnated with lime as to render it probable that brackish water species might easily adapt themselves to the change, while a pure fresh water species might not relish the solution of lime any more than the solution of salt, and we know how few fishes there are that can live for even an hour on being changed from fresh to salt, or salt to fresh, water. We have also the case of the Cuban blind fishes belonging to genera with their nearest representative in the family a marine form, and with the

Pl. 1

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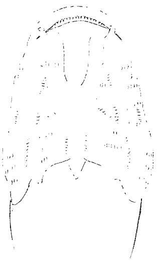

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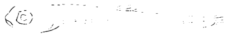

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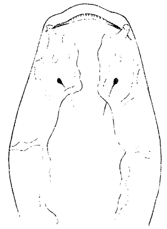

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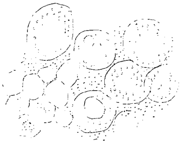

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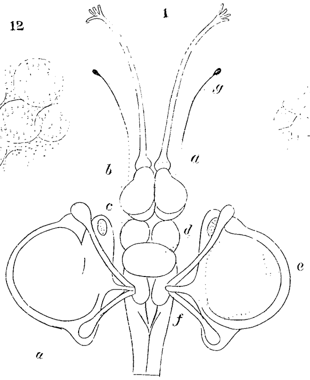

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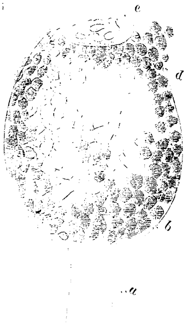

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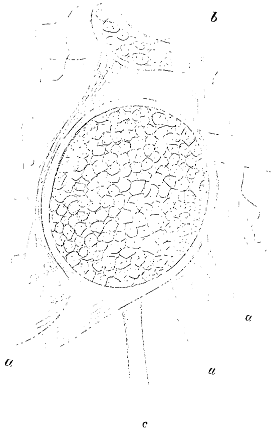

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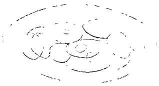

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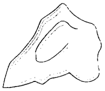

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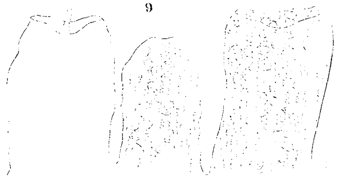

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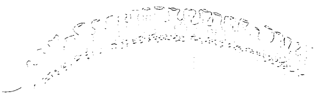

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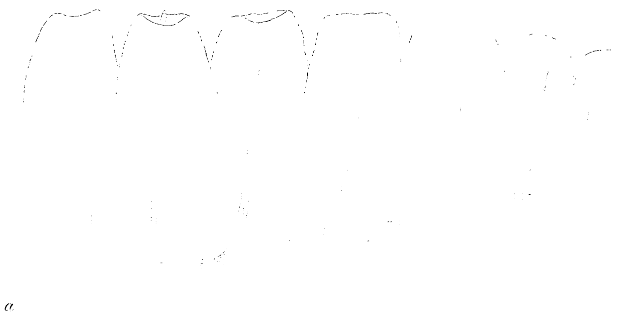

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C. A. WALKER SC.

whole family of cods and their allies, to which group they belong, essentially marine. Further than this the cat fish from the subterranean stream in Pennsylvania belongs to a family having many marine and brackish water representatives. As another very interesting fact in favor of the theory that the Heteropygii were formerly of brackish water, we have the important discovery by Prof. Cope of the Lernæan parasite on a specimen of Amblyopsis from the Wyandotte cave; this genus of parasitic crustaceans being very common on marine and migratory fishes, and much less abundant on fresh water species.

Thus I think that we have as good reasons for the belief in the immutability and early origin of the species of the family of Heteropygii, as we have for their mutability and late development, and, to one of my, perhaps, too deeply rooted ideas, a far more satisfactory theory; for, with our present knowledge, it is but theory on either side.

EXPLANATION OF PLATES.

PLATE 1.

[All the figures on this plate are from original drawings by Prof. J. Wyman.]

FIG. 1. Brain, nerves and organ of hearing of *Amblyopsis spelæus;* enlarged; *a*, olfactory lobes and nerves; *b*, cerebral lobes; *c*, optic lobes; *d*, cerebellum; *e*, organ of hearing, showing the semicircular canals, with the otolite represented in place by the dotted lines; *f*, medulla oblongata; *g*, optic nerves and eye specks.

FIG. 2. Otolite, enlarged.

FIG. 3. Eye, magnified (natural size one-sixteenth of an inch in length); *a*, optic nerve; *b*, sclerotic membrane; *c*, layer of colorless cells; *d*, layer of pigment cells (iris ?); *e*, lens.

FIG. 4. Lens, enlarged and showing the cells.

FIG. 5. Eye, enlarged, showing the muscular bands, *a*, *a*, *a*, *a;* *b*, the lens pressed out of place; *c*, the optic nerve.

FIG. 6. Top of head, showing the canals under the skin, of the natural size. The two black dots and lines indicate the eyes and optic nerves in position.

FIG. 7. Top of head, showing the arrangement of the ridges of papillæ. Natural size.

FIG. 8. One of the ridges of papillæ from the head, magnified.

FIG. 9. Three of the papillæ from the ridge, still more magnified, showing the cup-shaped summit and projecting filament.

FIG. 10. A portion of the ridge magnified, and treated with acid, to show the arrangement of the nervous plexus supplying the papillæ with nerve filaments from a branch (*a*) of the fifth pair.

FIG. 11. Epithelial cells from the head.

FIG. 12. Epithelial cells from the body.

FIG. 13. A fish with eyes, found in the stomach of an Amblyopsis.

PLATE 2.

FIG. 1.	AMBLYOPSIS SPELÆUS DeKay. Natural size.
1*a*.	Stomach and pyloric appendages. Twice natural size.
1*b*.	Scale, magnified.
1*c*.	Abdominal cavity, showing position of stomach and single ovary. Natural size.
FIG. 2.	CHOLOGASTER CORNUTUS Agassiz. Natural size.
2*a*.	Stomach and pyloric appendages. Twice natural size.
2*b*.	Scale, magnified.
2*c*.	Abdominal cavity, showing stomach and single ovary behind the stomach. Twice natural size.
FIG. 3.	TYPHLICHTHYS SUBTERRANEUS Girard. Natural size.
3*a*.	Stomach and pyloric appendages. Twice natural size
3*b*.	Scale, magnified
FIG. 4.	CHOLOGASTER AGASSIZII Putnam. Natural size.
4*a*.	Stomach and pyloric appendages. Twice natural size.
4*b*.	Scale, magnified.

The scales figured on the plate are all from the second or third row under the dorsal fin. 4 *b* is represented with the posterior margin *down*, all the others are represented with the posterior margin on the *left*. The natural size of the scales is given by the minute outline at the left of the figures above each scale; 4 *b* is so small that the natural size can hardly be represented by the black dot.

NOTE TO ARTICLE IN DECEMBER NUMBER, BY A. S. PACKARD, JR.

Since my article was printed, Prof. Cope's article entitled "Life in the Wyandotte Cave" has appeared in the "Annals and Magazine of Natural History" (London) for November. He enumerates the following articulates as inhabitants of this cave; "*Anophthalmus Tellkampfii*, and another species; two species of Staphylinidæ; Raphidophora; two species of flies; an Aranea-like and Opilio-like spider; a species of Pseudotremia; Cambarus pellucidus, an unknown aquatic Crustacean with external egg pouches, and a Lernæan (crustacean) parasitic on the blind fish. Of these one beetle (Anophthalmus), the cricket (Raphidophora), a fly, the Opilio-like spider, the centipede, and the blind crawfish, are probably the same as those found in the Mammoth Cave. Two beetles and two crustaceans are certainly different from those of the latter, and the centipedes are much more numerous. The Gammaroid crustacean found in the waters of the Mammoth Cave, and which is, no doubt in part, the food of the blind fish, we did not find; but some such species no doubt exists, as we found an abundance of a lively little tetradecapod crustacean near the mouth of a cave close by."

A NEW ERECTING ARRANGEMENT, ESPECIALLY DESIGNED FOR USE WITH BINOCULAR MICROSCOPES.

BY R. H. WARD, M.D.

FOR dissecting and other manipulations under magnifying powers, the simple microscope is awkward and unsatisfactory, and has been made to serve as a binocular only with low powers; but the superb field of the compound microscope has been comparatively little used for these purposes because few persons can work to advantage under an inverting arrangement, the erectors usually